International Journal of Advanced Research in Engineering Technology & Science ISSN: 2349-2819
Impact Factor: 7.10
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Email: editor@ijarets.org Volume-13, Issue-1 January – 2026 www.ijarets.org

PHOTOLUMINESCENCE AND THERMOLUMINESCENCE SYNTHESIS, CHARACTERIZATION AND PROPERTIES OF BORATE BASED PHOSPHORS FOR RADIATION DOSIMATRY.

Dr N K Puraley

Assistant professor & HOD Department of Physics

Dr Jwala Prasad Mishra Govt Science College Mungeli Chhattisgarh

Abstract

Radiation dosimetry has shown a lot of interest in boron-based phosphors because of their chemical stability, capacity to host different activator ions, and outstanding luminous qualities. In this research, phosphor materials based on borate were created and studied for possible use in radiation dosimetry with the addition of the rare-earth ions dysprosium (Dy^{3+}) and europium (Eu^{3+}). The crystalline and homogeneous phosphor samples were generated using an appropriate synthesis approach, such as the combustion method or solid-state reaction. The produced phosphors were analyzed for their structural and morphological properties using imaging microscopy, Fourier transform infrared spectroscopy, and scanning electron microscopy. The XRD study verified the presence of a pure crystalline borate phase, and the SEM pictures showed that the particles had a consistent shape. Studies using photoluminescence (PL) showed that the borate host lattice efficiently transferred energy, as seen by the high emission peaks that corresponded to Dy^{3+} and Eu^{3+} ions. The fact that Dy^{3+} ions usually emitted blue and yellow light and Eu^{3+} ions red light proves that they are good luminescent activators. After exposing the phosphors to ionizing radiation, their thermoluminescence (TL) characteristics were studied. Clear peaks emerged from the glow curve study, suggesting the existence of solid trapping centers inside the substance. There was a positive correlation between the radiation dosage and the TL intensity, indicating high sensitivity to radiation. In addition, the materials showed good repeatability and fading characteristics, two things that are crucial for accurate dosimetric measurements. Dy^{3+} and Eu^{3+} doped borate phosphors show promise in optical and dosimetric characteristics, according to combined photoluminescence and thermoluminescence investigations. Radiation dosimetry, in which these materials might be useful, has several possible uses, including in the fields of medicine, ecology, and industry. Their luminescence efficiency and dosimetric performance might be improved with further tuning of dopant concentration and synthesis conditions.

Keywords: *Thermoluminescence, Photoluminescence, synthesis, dosimatry*

Introduction

Numerous domains rely heavily on radiation dosimetry, including treatment, environmental monitoring, nuclear enterprises, medical diagnostics, and space exploration. Ensuring safety, optimizing radiation doses, and minimizing negative biological consequences all rely on accurate monitoring of ionizing radiation. Because of their great sensitivity, stability, and capacity to retain radiation data for further

analysis, luminescent materials—particularly thermoluminescent and photoluminescent phosphors—have become an important component of radiation detection systems. A thermoluminescent dosimeter (TLD) is a device that measures radiation dosage by using the energy that specific materials store when exposed to ionizing radiation and then release as light when heated (McKeever, 1985). Radiation dosimetry has recently shown a lot of interest in borate-based phosphors as a potential material. Borate compounds are very transparent in the UV-visible range, have a large band gap, are thermally and chemically stable, and have a low effective atomic number, among other beneficial features. For these reasons, borate materials are great candidates for use as host lattices to include luminous activator ions. The crystal structure of borate hosts can be easily accommodated by various rare-earth dopants, and they are also reasonably easy to manufacture (Yamashita & Yamamoto, 2003). When phosphor materials are doped with rare-earth ions, their light characteristics are amplified. Due to their distinct electronic structures and well defined emission transitions, rare-earth elements like dysprosium (Dy^{3+}) and europium (Eu^{3+}) find extensive application as activators. The energetic transitions between the excited and ground states cause dysprosium ions to emit a bright blue and yellow light, but europium ions are recognized for their vivid red light, which comes from the $^5D_0 \rightarrow ^7F_J$ transitions. Because of these emissions, rare-earth doped phosphors are used in display devices, lighting, radiation detectors, and other optical and luminescent applications (Blasse & Grabmaier, 1994).

It is usual practice to assess the optical and dosimetric properties of phosphor materials using photoluminescence (PL) and thermoluminescence (TL) methods. To learn how well energy transfer mechanisms work, photoluminescence analysis is used to study the behavior of doped ions inside the host lattice, both when excited and when emitted. However, research into thermoluminescence sheds light on the processes of radiation-induced luminescence, including the trapping and recombination pathways. Effective dosimetric materials must have steady light peaks and appropriate trapping centers (Chen & McKeever, 1997). Because of their desirable luminous properties, rare-earth doped borate phosphors have been the subject of much research into possible radiation dosimetry applications. Photoluminescent emission and thermoluminescent response may be enhanced by incorporating Dy^{3+} and Eu^{3+} ions into borate hosts, which can introduce efficient luminescence centers and trap levels. Research into these materials is crucial for creating effective radiation-sensitive phosphors because it sheds light on the interplay between synthesis parameters, structural features, and luminescence behavior. Hence, rare-earth (Dy^{3+} and Eu^{3+}) doped borate-based phosphors are the subject of the current investigation, which aims to synthesize, characterize structurally, and evaluate their photoluminescence and thermoluminescence capabilities. Examining their optical performance and potential radiation dosimetry applications is the goal. The creation of more effective and dependable phosphor materials for radiation detection and monitoring systems might be aided by a better understanding of these characteristics.

Radiation Dosimetry and Its Scientific Significance

The measurement, computation, and evaluation of the absorbed dosage of ionizing radiation is the focus of radiation dosimetry, a significant scientific field. Radiation dosage measurement is crucial in several domains, including space exploration, industrial radiography, environmental monitoring, medical treatment, and nuclear power production. Radiation therapy has many medical uses, but one of the most important is cancer treatment. Accurate dosage calculations are necessary to target the tumor with enough radiation while protecting healthy tissues around it. Equally important for the safety of employees and the

environment is the monitoring of radiation exposure in research laboratories and nuclear sites. Several methods for measuring radiation exposure have been developed in the last several decades. These include thermoluminescent dosimeters, film dosimeters, semiconductor detectors, and ionization chambers. Thermoluminescent dosimeters (TLDs) are one type that has gained popularity for measuring radiation exposure because of its adaptability, reusability, and extreme sensitivity. while heated, thermoluminescent materials can release the energy they accumulated while exposed to ionizing radiation in the form of visible or ultraviolet light. Materials with a high radiation absorption rate and a high light emission intensity are ideal for dosimetry and radiation monitoring (McKeever, 1985). Understanding the optical behavior of phosphor systems relies on thermoluminescence and photoluminescence features of materials. Excitation and emission mechanisms, defect states, and energy transfer mechanisms in luminous materials can be better understood through photoluminescence investigations. For this reason, high-tech radiation detectors are in high demand for materials with thermoluminescence and photoluminescence capabilities.

Borate-Based Phosphors as Host Materials

The use of borate-based compounds as luminous phosphor host materials has garnered a lot of interest in recent years. Borate materials are well-suited for use in optical and dosimetric applications due to their many attractive features. Wide band gaps, strong thermal stability, low phonon energies, and great optical transparency in the UV and visible areas are characteristic properties of these materials. With these characteristics, luminescence may be efficiently achieved while non-radiative energy losses are minimized. Structural flexibility is an additional significant benefit of borate compounds. The structural units that make up borate networks can take several forms, including BO_3 triangles and BO_4 tetrahedra. Because of their structural variety, borate materials may accept a wide variety of dopant ions without drastically distorting their lattice structure. Borate hosts can efficiently incorporate rare-earth activators, which improves their luminous performance. In addition, the effective atomic number of borate-based phosphors is generally low, making them comparable to human tissue. Their ability to provide more precise dosage readings makes them ideal for use in radiation dosimetry in the medical and biological fields. Lighting, display, laser, and radiation detector applications have all been explored extensively for borate compounds due to their many benefits (Yamashita & Yamamoto, 2003).

DETERMINATION OF TL PARAMETERS

Kinetic characteristics, including trap depth, frequency factor, and order of kinetics, often determine the dosimetric features of thermoluminescence materials. The stability of the traps and the TL mechanism of phosphors may be inferred from these characteristics, as can the likelihood of retrapping the trapped charge carriers upon heating. The light peak will be seen at a cooler temperature and the associated trap will be unstable if the depth of the trap is shallow. The TL signal will fade at room temperature because of this, and the fading will be more noticeable at higher frequency factors. Some of the ways that thermoluminescence's process may be explained and TL parameters can be calculated include the initial rise technique, the peak shape approach, and the variable heating rate method.

Symmetry factor and order of kinetics

Randall-Wilkins Garlick-Gibson and May-Patridge have provided the first-, second-, and general-order kinetic equations, respectively, that regulate the thermoluminescence processes and describe the location,

form, and strength of the TL peak. The TL process's first-order kinetics equation was most clearly described by Randall and Wilkins It follows that the TL peak is a result of thermal electron release from traps and their recombination with holes in recombination centers. The equality between the rates of heat release of the electron and recombination is a necessary condition for certain assumptions. First, that there is a single recombination center and a single trapping state; second, that electrons are thermally freed from traps and recombine with trapped holes rapidly; and third, that it is impossible for an electron to accumulate in the conduction band. At a specific temperature (T), the release rate is directly proportional to the concentration of trapped electrons (n) and the Boltzmann exponential factor (exp). Proceeding from these premises, the first-order kinetic equation may be expressed as -.

$$I = -\frac{dn}{dt} = ns\,exp[-E/kt] \qquad \ldots\ldots\ldots\ldots (1)$$

The fact that n(t) decreases as time increases is shown by the negative sign. We may get a formula for 'n' as a function of temperature by supposing a heating function, T = T(t). Taking into account the basic linear heating function,

$$T = T_o + \beta t \qquad \ldots\ldots\ldots\ldots (2)$$

The heating rate is denoted by β, while the initial temperature is represented by To. Another way to represent n(t) is as,

$$n(T) = n_0\,exp[\,(-\frac{s}{\beta}\int_{T_0}^{T} exp\left(\frac{E}{kT'}\right)dT'] \qquad \ldots\ldots\ldots\ldots\ldots (3)$$

Therefore, we have, as a function of temperature, the TL intensity:

$$I(T) = n_0\,s\,exp\left(-\frac{E}{kT}\right)exp[\left(-\frac{s}{\beta}\right)\int_{T0}^{T} exp\left(\frac{E}{kT'}\right)\,dT'] \qquad \ldots\ldots\ldots\ldots\ldots (4)$$

The glow curve rises from its original state because the first exponential term dominates at temperatures slightly over To, while the second term dominates at higher temperatures. The dosimetric peak in first-order kinetics is asymmetric, meaning it falls at high temperatures beyond the maximum limit rather than rising. This is the most notable aspect of this kinetics model. Furthermore, variations in the starting concentration have no effect on the curve's form. The second-order dynamics of a single trap and a single recombination center model were addressed by Garlick and Gibson. Two presumptions underpin it: Retrapping and recombination are equally likely for the free charge carriers. (2) Throughout the procedure, the recombination center's holes and traps have an identical concentration of electrons. The kinetic equation may be expressed as follows in the event that the specified total number of traps is N:

$$I = -\frac{dn}{dt} = \left(\frac{s}{N}\right)n^2\,exp\left(-\frac{E}{kT}\right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

S' stands for S/N, which is measured in m3/s. Hence,

$$I = -\frac{dn}{dt} = s'n^2\,\exp\left(-\frac{E}{kT}\right) \qquad \ldots\ldots\ldots\ldots\ldots (6)$$

Once more, as with first-order kinetics, we may think of a linear heating function and use it to solve a second-order partial differential equation, which yields,

$$I(T) = n_0^2 s' \exp\left(-\frac{E}{kT}\right)[1 + \left(\frac{n_0 s'}{\beta}\right)\int_{T_0}^{T} \exp(-E/kT')dT']^{-2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

The glow curve is almost symmetrical with the high-temperature half being somewhat broader than the low-temperature half; this is the most notable aspect of the equation. The exponential term exp(-E/KT) dominates the initial ascent of the glow curve, just as it does in the first-order kinetic. The product function drops as a result of the second term's dominance at high temperatures; when the starting concentration increases, the peak moves to a higher temperature. The TL emission on the high-temperature side is somewhat spread out before they join because the released electrons are concentrated and must be retrapped, which delays TL First, for the general order TL kinetic, May and Patridge proposed the following empirical relation:

$$I = n^b s' exp(-E/KT) \qquad \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

The dimensions of s' are m3(b-1) s1, and b is the kinetic order, which can be anything from 1 to 2. Because the dimensions of the parameter s' change with the order of kinetics, solving the empirical equation becomes a major challenge when trying to grasp its physical significance. By changing equation (8) to this form, Rasheedy [51] was able to solve this problem.

$$I = -\frac{dn}{dt} = \left(\frac{n^b}{N^{b-1}}\right) s \exp\left(-\frac{E}{kT}\right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Assuming b = 1, this equation may be simplified to (1), and assuming b = 2, it can be simplified to (5), both of which are second order kinetic equations. In solving equation (9), the result is

$$I = n_0^b s \exp\left(-\frac{E}{kT}\right) N^{1-b}\,[1 + \frac{s(b-1)\left(\frac{n_0}{N}\right)^{b-1}}{\beta}\int_{T_0}^{T} \exp\left(-\frac{E}{kT'}\right)dT']^{-\frac{b}{b-1}} \ldots\ldots\ldots(10)$$

The equation (10) is also a empirical relation, which removes the difficulty in understanding the meaning of parameter s'.

Initial rise method

Independent of the sequence of kinetics, Garlick and Gibson proposed the easiest way to find the trap depth of TL materials. It is predicated on the idea that for all values of T ≤ Tm and all values of I ≤ Im, the quantity of trapped electrons remains almost constant at the upward portion of the glow curve, and the relationship between n(T) and temperature T is almost nonexistent.

The TL emission can be written as I (t) α exp (-ε/KT) …….(11)

Where Tm is the maximum temperature at which the glow occurs and Im is the maximum intensity. The trap depth may be determined by plotting the logarithm of intensity versus 1/T, which yields a straight line with a slope corresponding to (-E/K).

Peak shape method

The geometry of the Tl glow peaks is practically symmetrical when they correspond to second-order kinetics and asymmetrical when they correspond to first-order kinetics. Using the peak temperature (TM) and two temperatures corresponding to the half peak intensity on the rising end (T1) and falling end (T2) of the glow curve, one can infer the trap depth, frequency factor, and order of kinetics from the geometrical features and glowing shape of the glow peak. By utilizing the glow curve shape, we were able to compute the overall peak width at half maximum intensity (ϋ = T2 - T1), the lower temperature half-width (τ = TM - T1), and the upper-temperature half-width (δ = T2 - TM). Additionally, we were able to derive the symmetry factor (μg = δ/ϋ). One way to get the kinetic order from a Chens plot is to use the symmetry factor.

Variable heating rate

The heating rate is a critical variable that determines where the TL glow curve peaks during TL reading of any kinetic order. The temperature that corresponds to the highest TL peak intensity is sensitive to variations in the linear heating rate. To find the trap depth, Booth proposed using two heating rates:

$$E = k\frac{T_{M1}T_{M2}}{T_{M1}-T_{M2}}\ln\left[\frac{\beta_1}{\beta_2}\left(\frac{T_{M2}}{T_{M2}}\right)^2\right} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

$$s = \frac{E}{k}\exp\left\{\left[\frac{T_{M2}\ln\frac{T_{M2}^2}{\beta_2} - T_{M1}\ln\frac{T_{M1}^2}{\beta_1}}{(T_{M1}-T_{M2})}\right]\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

This is where the formula is defined: E is the depth of the trap, TM1 and TM2 are the highest points that may be reached at linear heating rates β1 and β2, and k is the Boltzmann's constant.

THERMOLUMINESCENCE PROPERTIES OF BORATES

Magnesium tetraborate (MTB) and lithium tetraborate (LTB) are phosphors based on borates that are almost tissue equivalent. With its many possible uses and TL characteristics, lithium tetraborates (LTB) are an exciting new material. An appealing TLD material for individual dosimetry, lithium borate crystal has an effective atomic number of7.3, which is near to that of biological tissue, which is 7.42. The compound lithium tetraborate (Li2B4O7) has a low density and a melting point of 916 °C, with a specific gravity of 2.45 g/cm3. The space group I41cd and the point group C4v are used to identify the crystal structure of LTB. It is composed of a covalent network with the formula =B-O-B⋟. This network is stabilized by Li+ ions that are accommodated inside it and has a frame of alternating oxygenbonded BO4 and BO3 oxyanions. Lattice parameters a = b = 9.47 Å and c = 10.26 Å characterize the tetragonal structure of the LTB crystal, which is based on the cradle-like B4O7 group.

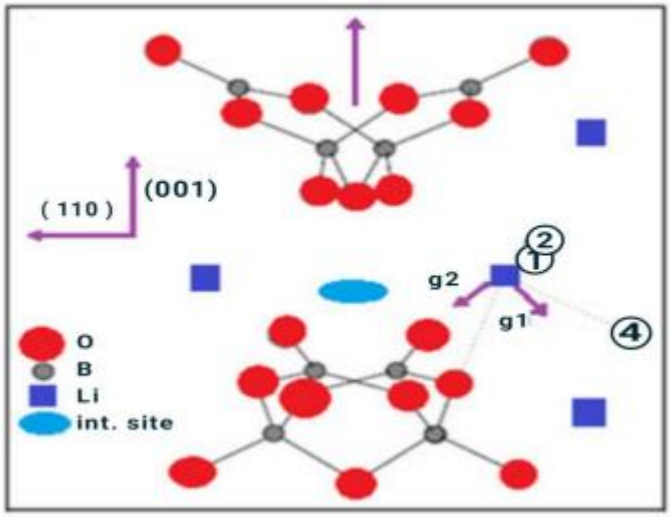

Fig. 1 - The Li2B4O7 lattice structure is displayed as a portion of the tetragonal elementary cell's projections along a -type axis.

Among LTB's many appealing qualities are its strong radiation resistance, broad operating dosage range, and many real-world applications. Lithium tetraborate doped with manganese was the first TL dosimetry material based on borate. Red emission (600 nm) was incompatible with the photomultiplier tubes' spectral response, which resulted in a lower sensitivity for this TL dosimetry material. The sensitivity of LTB materials was amplified by a factor of ten when copper was doped into them, and their emission wavelength changed from the red to the UV (360 nm) area. Dopants like silver, phosphorus, magnesium, indium, or a mix of these can further enhance the sensitivity of TLD materials. Garret et al. created the initial LTB single crystals that were utilized for infrared transmission research. To study the structural properties and understand the mechanism of LTB phosphors, several research groups reported the synthesis of LTB single crystal. The sintering approach was initially used to manufacture polycrystalline powder samples of doped LTB phosphors in 1980. Afterwards, this method was employed to create LTB phosphors and investigate their dosimetric properties. Powder and pellet samples of Mn-doped lithium tetraborate LTB, which was produced using the solution combustion process, were examined for their thermoluminescence dosimetric properties by Ozdemir et al.. The initial components, boric acid H3BO3 and lithium nitrate LiNO3, were added in a stoichiometric ratio.

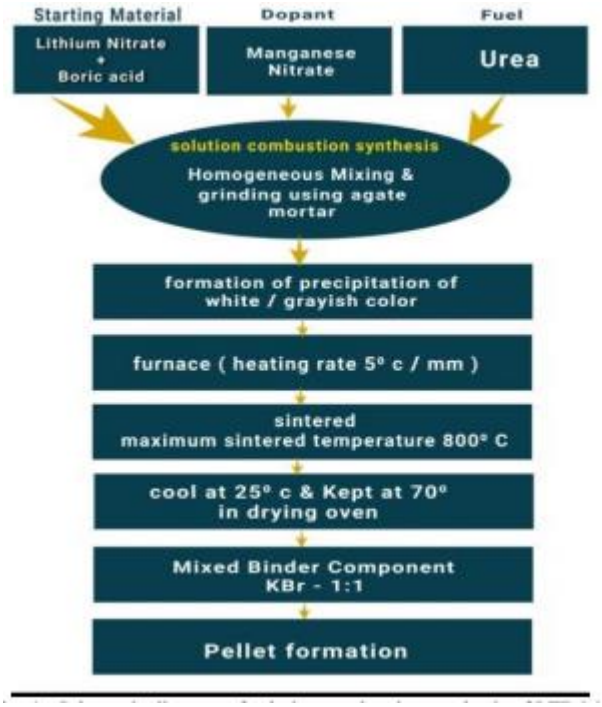

Fig. 2 - Schematic diagram of solution combustion synthesis of LTB:Mn

Using 90Sr/90Y sources, beta radiation was administered to Mn-containing materials at room temperature to determine their dosimetric characteristics. There was a dosage rate of 6.689 Gy/min. Powder and pellets of LTB: Mn subjected to a 2 Gy beta dose were studied for their TL curves. Figure 3rature peak utilized in the TL emission measurements, the second TL peak is located at around 260 °C. The identical TL peaks seen for the LTB have been reported in other publications in recent years.

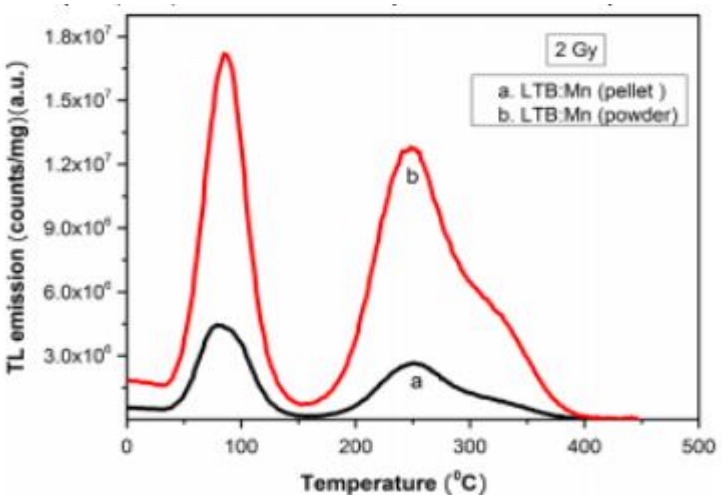

Fig. 3 - TL glow curves for Li2B4O7:Mn powder and pellet samples exposed to 2 Gy beta dose.

The Tm-Tstop approach, in conjunction with the IR method and the CGCD methodology, verified subsequent to the 5 Gy beta treatment that the high-temperature glow peak could be divided into three TL peaks centered at 220, 268, and 292 °C, with the characteristics listed in Table1.

Table 1: Kinetic parameters estimated using IR and CGCD methods.

	Activation Energy E_a (eV)	Kinetics Order (b)	Frequency Factor (s) s^{-1}	Methods
P1 220°C	1.03 ± 0.12 0.95 ± 0.01	- 1.46 ± 0.05	- $5.74 \cdot 10^{8}$	IR CGCD
P2 268°C	1.22 ± 0.05 1.22 ± 0.01	- 1.78 ± 0.07	- $2.32 \cdot 10^{10}$	IR CGCD
P3 292°C	1.45 ± 0.04 1.44 ± 0.01	- 1.87 ± 0.05	- $5.65 \cdot 10^{11}$	IR CGCD

Important metrics, such as a linear dose-response at low doses up to 10 Gy, have been uncovered by studying the recycling and fading properties of the investigated phosphor. Figure 4 shows that up to 100 Gy, the dose-response curve exhibited superlinearity features when exposed to beta rays, and that the TL intensity grows linearly for both powder and pellets of LTB: Mn samples. Powder LTB: Mn samples have a relative sensitivity that is ten times lower than that of TLD100 following a beta dose exposure of 10 Gy. The literature reports LTB: Mn with varying doses of Mn, which yielded consistent findings in dose-response tests. Annalakshmi et al. have found similar outcomes for dose values up to 10Gy with photon response of 0.32 wt% Mn-doped Li2B4O7. Two sets of samples exhibited supra-linearity at doses ranging from 1 to 500 Gy in Danilkin et al.'s study of TL dose dependence for Mn-doped Li2B4O7.

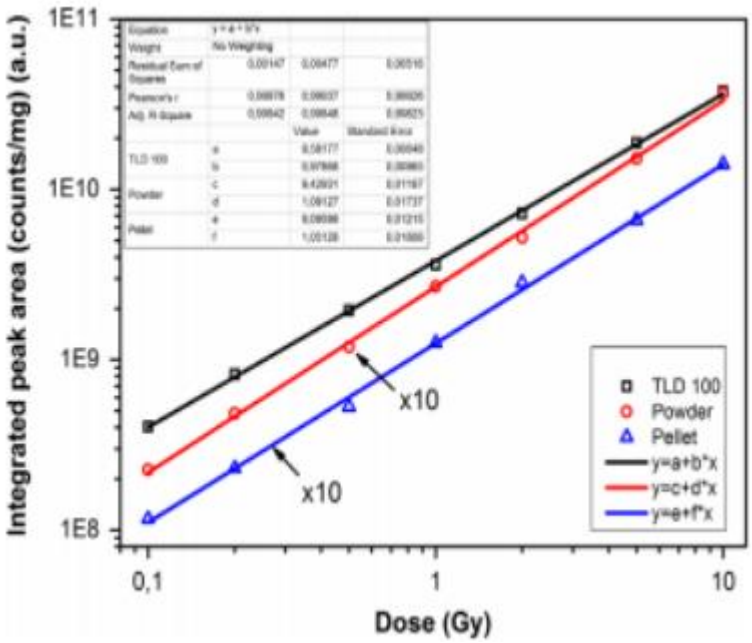

Fig. 4 - Dose response of powder and pellets LTB:Mn and TLD-chips exposed to beta rays

At 40-80 keV and 662 keV, the predicted low photon energy dependency (less than 1MV) of LTB: Mn was somewhat greater than that of high energy photons. After 30 days of exposure to a 1 Gy beta dosage in a dark, room-temperature environment with a relative humidity of around 46% RH, the fading effect of LTB: Mn was evident in powder samples that had been kept recently. In three hours, there was noticeable fading at a low-temperature peak, and by twelve hours, it had vanished entirely. The fading impact was 10% after one month at a very extreme peak temperature of 260 °C. Within a week, we saw a 27% fade,

but after a month, we saw a 10% overall fade. The LTB samples exhibited strange fading behavior with a little peak at the beginning of the curve, in contrast to the regular decay shown in earlier studies for the different phosphors.

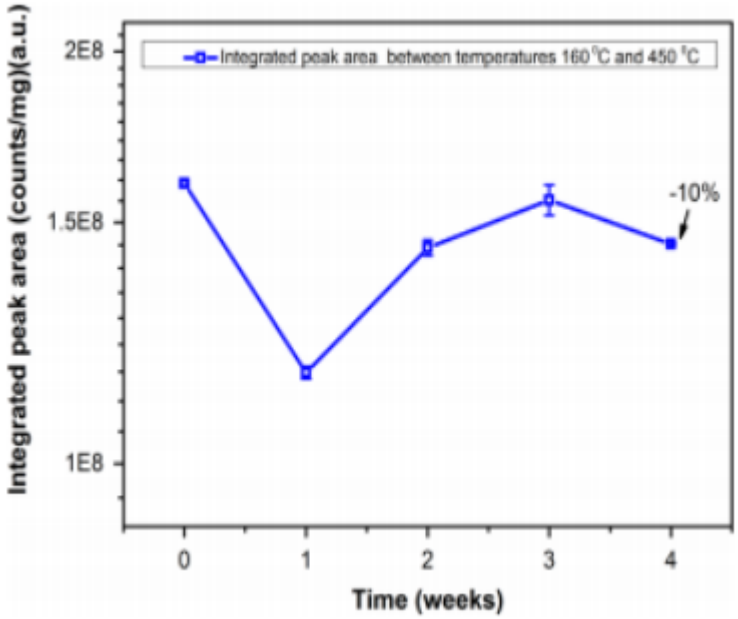

Fig. 5 - Effect of fading after different periods of storage in the dark and room temperature

A promising material was found to be LTB: Mn 0.04M% phosphor. Clinical therapeutic dosimetry is one area where this type of TLD material might be useful for ionizing radiations. Not only that, but LTB compounds are efficient materials in many diverse scientific and industrial applications, including piezo-technology, acoustic electronics, and nonlinear optics. The Ag-doped LTB crystals were prepared by Kurali et al. using the czochralski process . There was 0.25 weight percent of silver in the LTB. The Czochralski technique was used to generate single crystals of LTB, which were subsequently cut into 5x3x1 mm dimensions and polished. Figure 5 shows that when heated at a rate of 5 °C/s between 50 and 250 °C, the TL glow curve of an Ag-doped LTB single crystal exhibits four distinct peaks at 75, 130, 190, and 275 °C, in contrast to undoped LTB, which exhibits a wide peak at 125 °C and a sharp peak at 190 °C. According to Petra et al. who similarly used the czochraslki technique in ambient air to study the LTB: Ag single crystal, they found a single strong peak at -155 o c within the temperature range of 50 - 250 o c. This is because the size of the Li+ ions (76 pm) and the Ag+ ions (115 pm) varies significantly.

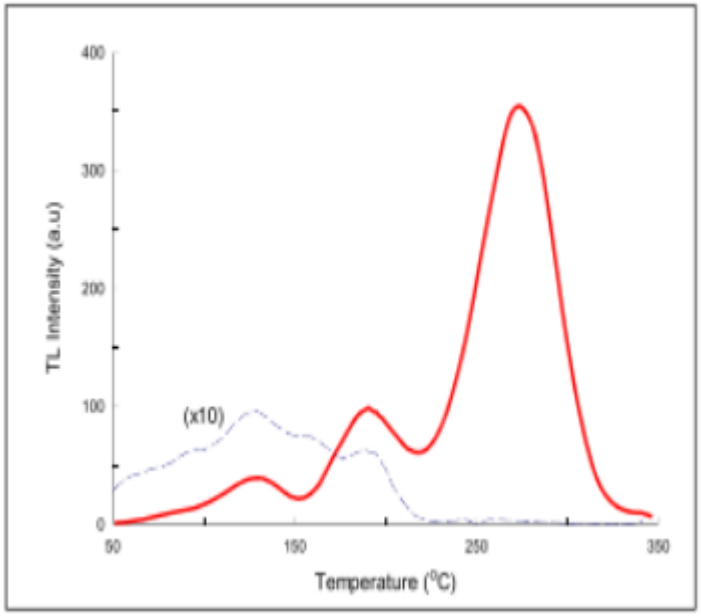

Fig. 6- Comparison of TL glow curves of undoped (dashed line) and Ag-doped (solid line) LTB single crystals, exposed to β radiation (600 mGy) from a 90Sr– 90Y source at room temperature.

The dose-response curves of the single crystals doped and undoped with Ag reveal that the peak of Ag: LTB at 275 °C exhibits a linear response from 33 to 800 mGy, and a sublinear area from 1 to 9 Gy, as seen in figure 9. A linear response was detected in the range of 1 to 9 Gy for the undoped single crystal, as shown in figure 10, whereas a supralinear response was observed for low doses.

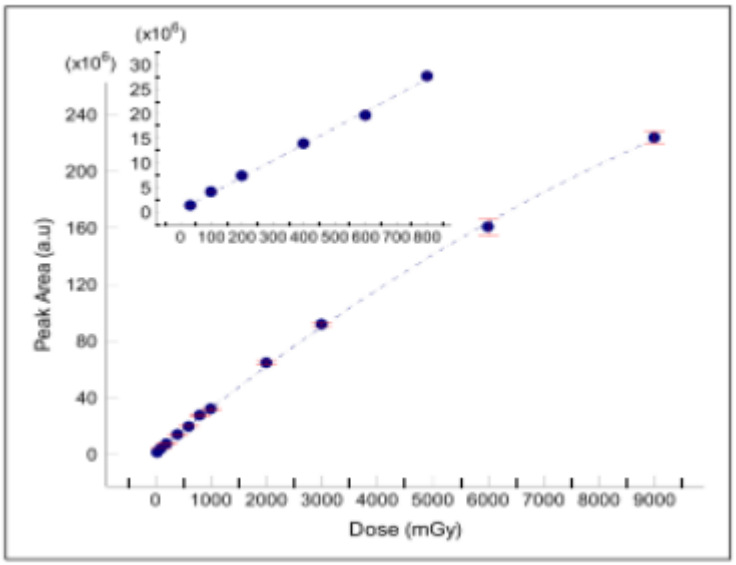

Fig. 7 - TL Dose response of LTB:Ag single crystal

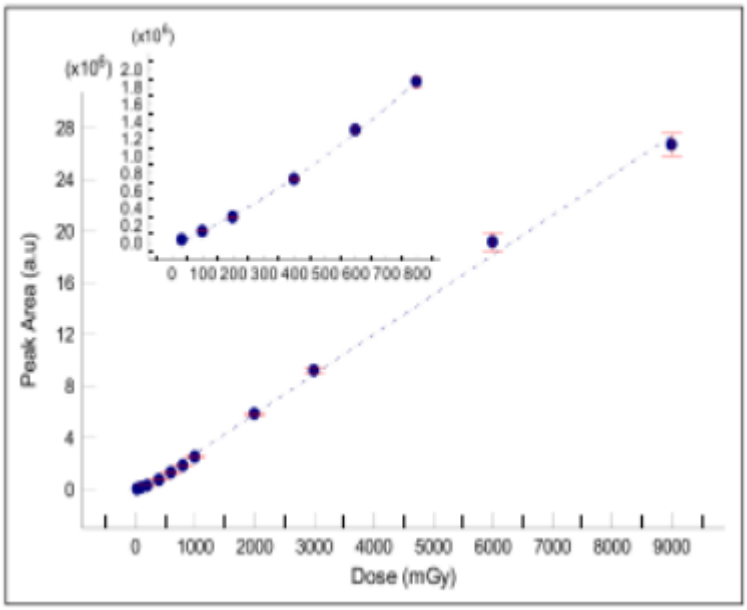

Fig. 8 - TL dose–response of undoped LTB single

After being annealed and exposed to beta rays at 100 and 600 mGy, the samples were left in the darkroom for seven days to determine the thermal fading ratio of LTB: Ag and undoped single crystal. Over the course of 7 days, Ag-doped LTB demonstrated distinct behavior compared to undoped LTB, which exhibited 60% fading for the high-temperature peak. Under the identical experimental circumstances, there was no significant change in the TL responses of Ag-doped and undoped single crystals following the ten measurement cycles. Li2B4O7: Ag has a TL sensitivity that is five times lower than TLD-100, making it an excellent choice for radiation dosimetry, especially in areas with high doses.

Conclusion

In this research, phosphor materials based on borate were produced and studied for possible use in radiation dosimetry after being doped with the rare-earth ions dysprosium (Dy^{3+}) and europium (Eu^{3+}). Using photoluminescence and thermoluminescence investigations, the study aimed to investigate the optical, luminescent, and structural properties of these phosphor materials. Due to their structural flexibility, large band gap, and excellent chemical stability, borate compounds were shown to be an efficient host lattice for integrating rare-earth dopants. The production of crystalline borate phases was validated by the structural characterisation of the produced phosphors. The crystal structure was not significantly altered by the presence of Dy^{3+} and Eu^{3+} ions in the host lattice. The presence of rare-earth ions is crucial for improving luminous characteristics, and this suggests that borate materials have a robust structure that can accommodate their inclusion. Dopant ions are evenly distributed throughout the host lattice, which improves optical performance and allows for effective luminous emission. Research into photoluminescence has confirmed that Dy^{3+} and Eu^{3+} ions are powerful luminous activators, as it has shown distinct emission bands linked to these ions. Phosphors doped with Dy^{3+} displayed distinct emission bands in blue and yellow, but phosphors doped with Eu^{3+}, thanks to their famous electronic transitions, emitted strong red light. The emissions in question are produced by intra-4f electronic transitions, which are not very affected by the host environment and so exhibit steady and crisp emission spectra. Based on the photoluminescence results, the produced phosphors are very effective optical materials with a wide

range of potential luminous uses. Additional thermoluminescence studies confirmed the high radiation sensitivity of the doped borate phosphors. Ionizing radiation induced distinct light peaks in the samples, which pointed to the existence of stable trapping centers embedded in the crystal structure. The radiation-induced energy is stored by these trapping centers and then released as light during regulated heating. It is desired for dosimetric applications that the thermoluminescence intensity increases with increasing radiation exposure, since this indicates a proportionate and predictable response. Finally, a promising family of luminous materials for use in radiation detection systems are borate-based phosphors triggered with rare-earth ions. They have the potential to be enhanced in terms of luminescence efficiency and dosimetric performance with more study into optimising dopant concentration, synthesis conditions, and trap designs. Progress in this area may pave the way for phosphor materials that are both effective and safe to use in fields including environmental protection, medical diagnostics, and radiation monitoring.

References

[1] Blasse, G., & Grabmaier, B. C. (1994). Luminescent Materials. Berlin: Springer.
[2] Chen, R., & McKeever, S. W. S. (1997). Theory of Thermoluminescence and Related Phenomena. Singapore: World Scientific.
[3] McKeever, S. W. S. (1985). Thermoluminescence of Solids. Cambridge: Cambridge University Press.
[4] Yamashita, T., & Yamamoto, N. (2003). Luminescent properties of rare-earth activated borate phosphors. Journal of Luminescence, 100(1–4), 325–332.
[5] Deluca, J.A. (1980). Journal of Chemical Education, 57, 541 – 545 fig. (1).
[6] Murthy, K. V. R., and Virk, H. S. (2014). Defect and Diffusion Forum, 347, 1 - 34.
[7] Mckinlay, A.F. (1981). Medical Physics Handbook of Thermoluminescence Dosimetry. Adam Hilger Ltd, Bristol in collaboration with the Hospital Physicists Association.
[8] Mckeever, S. (1985). Thermoluminescence of Solids. Department of Physics, Oklahoma state university, Cambridge University press.
[9] Mckeever, S.W.S., and Chen, R. (1997). Theory of thermoluminescence and Related Phenomena. World scientific, Singapore.
[10] Becker K. (1973). CRC Press, Inc., Cranwood Parkway, Cleveleand, Ohio 44128, U.S.A.
[11] Wiedemann, E., and Schmidt, G.C. (1895). Über luminescenz. Ann. Physik., 54, 604-625.
[12] E.Wiedemann, E. (1889). Zurmechanik des leuchtens. Ann. Phys-Berlin., 37, 177- 248.
[13] Eduardo, G., Yukihara, Stephen, W. S., and McKeever, (2011). Optically Stimulated Luminescence: Fundamentals and Applications, John Wiley & Sons., UK.
[14] Trowbridge, J., & Burbank, J.E. (1898). Am. J. Sci., Ser. 4, 5, 55.
[15] Curie, M. (1961). Radioactive Substances, New York: Philosophical Library.
[16] Bull, R.K. (1986). Thermoluminescence and its Applocations: An Introduction. Nucl. Tracts Radiat. Meas., 11, 105-113.
[17] Wick, F.G., and Slattery, M.K. J. Opt. Soc. Amer 16, 398. [14] Wick, F.G., and Acad, S.B. (1938) Wiss Wien IIa, 139, 497
[18] Przibram, K. (1956). Irradiation Colours and Luminescence, (Pergamon Press London, London)
[19] Randall, J.T., and Wilkins, M.H.F. (1945). Proc. Roy. Soc. A 184, 346.
[20] Garlick, G.F.J., and Gibson, A.F. (1948). Proc. Phys. Soc. 60, 574.
[21] May, C.E., and Patridge, J.A. (1964). J.Chem. Soc. 40, 1401.

[22] Barthe J.R., Bohm, J., Christeasen, P., Driscoll, C.M., Harvey, J.R., Julius, H.W., Marshall, M., Marshall, T.O. and Oberhoffer, M. (1987). report on a Workshop on "The Application of Thermoluminescence DosimetryTo Large Scale Individual Monitoring". Ispra, 11-13 september, 1985, Radiation Protection Dosimetry, Vol. 18. No.1. pp 47-61.
[23] Li, J., Hao, J. Q., Li, C. Y., Zhang, C. X., Tang, Q., Zhang, Y. L., Su, Q. and Wang, S. B. (2005). Radiat.Meas. 39, 229.
[24] Madhukumar, K., Varma, H. K., Komath, M., Elias, T. S., Padmanbhan, V. and Nair, C. M. K. (2007). Bull. Mater. Sci. 30, 527.
[25] Pradhan, A. S. (1981). Radiation Protection Dosimetry, 1 (3), 153-167.
[26] Ege, A. T., Ekdal, E., Karali, T., and Can, N. (2007). Radiation Measurements, 42, 1280-1284.
[27] Sunta, C.M. (2015). Unraveling Thermoluminescence, Springer Series in Material Science, Springer Science + Business Media,
[28] Rey, L., Gartia, R.K., Bishal K., Singh and Th. Basanta Singh, (2009). Nucl. Instr. and Meth. in Phys. Res. B, 267, 3633.
[29] Nambi, K. S. V., Kathuria, S. P., and Sunta, C. M. (1969). Radiation Protection Monitoring, IAEA, Viena, 321.
[30] Withnall, R., and Silver, J. (2012). Physics of light emission from rare-earth doped phosphors, Handbook of Visual Display Technology, 1019-1028, Springer-Verlag Berlin Heidelberg 2012 ed., Janglin Chen Industrial Technology Research Institute Taiwan Wayne Cranton Nottingham Trent University UK Mark Fihn Veritas et Visus USA.

[31] Kitis G., Furetta C., Prokic M., amd Prokic V. (2000). J. Phys D: Appl Phys. 33, 1252.
[32] Randall, J.T., and Wilkins, M.H.F. (1945). Proc. Roy. Soc. A 184, 346.
[33] Garlick, G.F.J., and Gibson, A.F. (1948). Proc. Phys. Soc. 60, 574.
[34] May, C.E., and Patridge, J.A. (1964). J.Chem. Soc. 40, 1401.
[35] Chen R., and Winer S.A.A. (1970). J. Appl. Phys. 41, 5227.
[36] Booth A.H., and Can J. (1954). J. Chem. Ottwa. 32, 214.
[37] Nambi K.S.V. (1977). Thermoluminescence: its understanding and applications, Atomic Energy Agency Publications, Sao Paulo, Brasil.
[38] Furetta C., and Pellegrini R. (1981). Some dosimetric properties of Li2O7:Mn (TLD-800), Radiat. Eff. Defects Solids, 58, 17–23.
[39] Horowitz Y.S. (1984). Thermoluminescence and thermoluminescent dosimetry, CRC Press, Boca Raton, FL.
[40] Kuralı D., Ekdal K.E., Kelemen A., Holovey V., Can N. and Karalı T. (2016). Thermoluminescence characterization of Ag-doped Li2B4O7 single crystal materials. journal of biological and chemical luminescence, 32, Pp 786–790.
[41] Patra G.D., Singh S.G., Singh A.K., Tyagi M., Desai D.G., Tiwari B., Sen S., and Gadkari S.C. (2015). Silver doped lithium tetraborate (Li2B4O7) single crystals as efficient dosimeter material with sub-micro-Gy sensitivity. J. Lumin. 157, 333.
[42] Kazankaya V. A., Kuzmin V.V., Minaeva E.E., and Sokolov A.D. (1974). Proc. 4th Int.Conf. Luminescence Dosimetry, Kracow, Poland, 581.
[43] Prokic M. (1980). Development of highly sensitive CaSO4: Dy/Tm and MgB4O7: Dy/Tm sintered thermoluminescent dosimeters. Nucl. Instrum. Methods, 175, 83.
[44] Prokic M. (1986). Magnesium Borate in TL Dosimetry. Radiat. Prot. Dosim. 17, 393-396.